Macroscopic Volume Change of Dynamic Hydrogels induced by Reversible DNA Hybridization

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Supporting Information

Acrydite. The acrydite used in DNA sequences was prepared by a two-step synthesis. First, a mixture of 6-amino-1-hexanol (9.32g, 0.08mol) and TEA (16.16g, 0.16mol) in 100mL dichloromethane was cooled to 0 ^{o}C. Methacryloyl chloride (10g, 0.0957mol) was added slowly, and the reaction was stirred at 0 ^{o}C for 2 hours, after which 100mL of water was added to quench the reaction. The organic layer

was washed with 5% HCl and dried. After evaporation of all solvent, the crude 6-hydroxyhexyl methacrylamide was used for the next step without further purification. To a solution containing 6-hydroxyhexyl methacrylamide (2 g, 10.8 mmol) in anhydrous CH_3CN (40 mL) at 0 °C, N, N' Diisopropylethylamine (DIPEA) (3.9 g, 30.0 mmol) was added in 15 minutes. Then, 2-cyanoethyl diisopropyl chlorophosphoramidite (2.9 ml, 13 mmol) was added dropwise, and the reaction mixture was stirred at 0 °C for 5 h. After removing the solvent, the residue was dissolved in ethyl acetate, and the organic phase was washed with $NaHCO_3$ solution and NaCl solution and dried over anhydrous magnesium sulfate. The solvent was evaporated, and the residue was purified by column chromatography (ethylacetate/hexane/triethylamine 40:60:3) and dried to afford the title compound (3.33 g, 8.64 mmol, 80%) as an colorless oil. ^{1}H NMR ($CDCl_3$): δ 5.92 (br, 1H), 5.63 (m, 1H), 5.27 (m, 1H), 3.86-3.72 (m, 2H), 3.66-3.49 (m, 4H), 3.30-3.23 (m, 2H), 2.61 (t, 2H), 1.92 (m, 3H), 1.58-1.50 (m, 4H) 1.37-1.32 (m, 4H) 1.17-1.13 (m, 12H). 13C NMR ($CDCl_3$): δ 168.6, 140.4, 119.3, 118.0, 63.8, 63.6, 58.6, 58.3, 43.2, 43.1, 39.8, 31.3, 29.7, 26.8, 25.8, 24.9, 24.8, 24.7, 19.0. ^{31}P ($CDCl_3$): δ 148.

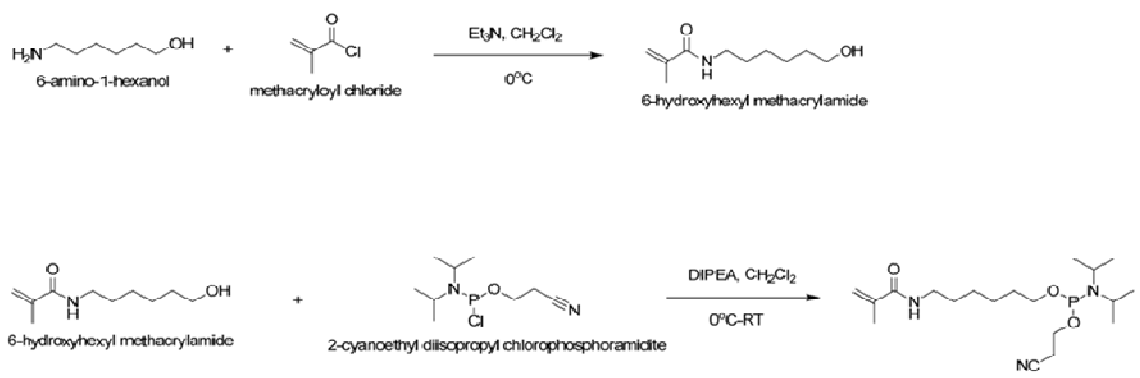

Figure S1. Synthesis of acrydite

Azobenzene phosphoramidite. Azobenzene phosphoramidite was synthesized according to the protocol reported by Asanuma et al.[1]**Compound 1**. In a roundbottom flask, a solution of D-threoninol (0.91g, 9.0mmol), 4-(phenylazo) benzoic acid (2.25g, 10.0mmol), dicyclohexylcarbodiimide (DCC)

(2.05g, 10.0mmol) and 1-hydroxybenzotriazole (HOBt) (1.32g, 10.0mmol) in DMF (50mL) was stirred under an argon atmosphere at room temperature for 24 hours. The reaction mixture was filtered and then concentrated by evaporation. The residue was purified by column chromatography (ethyl acetate/methanol 20/1) and dried to afford compound 1 (2.34g, 7.48mmole, 83%) as an orange solid. ^{1}H NMR ($CDCl_3$): δ 7.96-7.38 (m, 9H), δ 7.12 (d, 1H), δ 4.33 (m, 1H), δ 4.09 (m, 1H), δ 3.98 (d, 2H), δ 1.29 (d, 3H).

Compound 2. To a solution containing compound 1 (0.8g, 2.4mmol) and 4-dimethylaminopyridine (DMAP) (0.015g, 0.12mmol) in dry pyridine (10mL) at 0°C, 4,4-dimethoxytrityl chloride (DMT-Cl) (1.0g, 3.0mmol) in CH_2Cl_2 (4mL) was added dropwise. The mixture was stirred for 1 hour at 0°C and then at room temperature for another 24 hours. The solvent was evaporated, and the residue was an orange-red oil, which was purified by column chromatography (ethyl acetate/hexane/triethylamine 50:50:3) and dried to afford 2 (0.76g, 1.24mmol, 52%) as an orange-red solid. ^{1}H NMR ($CDCl_3$): δ 8.00-6.78 (m, 23H), δ 4.25 (m, 1H), δ 4.17 (m, 1H), δ 3.77 (s, 6H), δ 3.60 and 3.42 (dd, 2H), 1.23 (d, 3H).

Compound 3. To a solution containing 2 (0.62g, 1.0mmol) in anhydrous acetonitrile (20mL) at 0 °C, N, N'-diisopropylethylamine (DIPEA) (0.39g, 3.0mmol) was added over 15 minutes. Then, 2-cyanoethyl diisopropylchlorophosphoramidite (290μL, 1.3mmol) was added dropwise, and the reaction mixture was stirred at 0°C for 5 hours. After removing the solvent, the residue was dissolved in ethyl acetate, and the organic phase was washed with $NaHCO_3$ and NaCl solutions and dried over anhydrous magnesium sulfate. The solvent was evaporated, and the residue was purified by column chromatography (ethyl acetate/hexane/triethylamine 40:60:3) and dried to afford 3 (0.52g, 0.64mmol, 64%) as an orange-red solid. ^{1}H NMR ($CDCl_3$): δ 8.00-6.79 (m, 22H), δ 6.62 (d, 1H), δ 4.48 (m, 1H), δ 4.39 (m, 1H), δ 4.21-4.10 (m, 2H), δ 3.77 (s, 6H), δ 3.57-3.34 (m, 4H), δ 2.76-2.72 (m, 2H), δ 1.30-1.25 (m,

15H). ^{31}P ($CDCl_3$): δ 149.

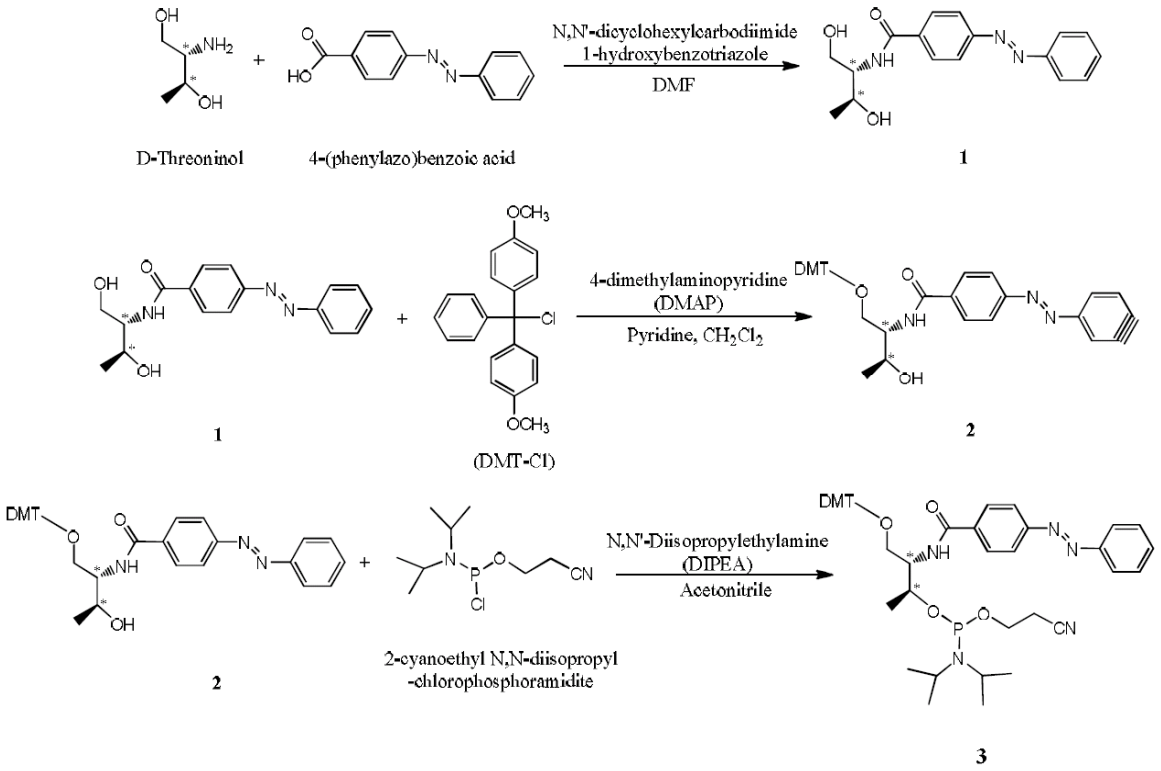

Figure S2. Synthesis of azobenzene phosphoramidite

Table S1. DNA sequences used in the experiments

Name	Sequence
A	5'-acrydite- TTT TTC ACA GAT GAG T-3'
A'	5'-acrydite- TTT TAC -azo-TC -azo-AT -azo-CT -azo-GT -azo-GA-3'
Ctrl-A'	5'-acrydite- TTT TAC TCA TCT GTG A-3'
B	5'-acrydite-TTT TTT TTT TTT TTT T

Table S2. Initial swelling ration after of hydrogels synthesized at different MBAA concentrations (0.5 mM DNA monomer, 10% acrylamide)

MBAA (MV%)	0.0033	0.0067	0.0135
Mass swelling ratio	8.2±0.5	6.1±0.3	4.2±0.3

Table S3. Initial swelling ration after of hydrogels synthesized at different DNA monomer concentrations (0.0033 % MBAA, 10% acrylamide)

DNA monomer (mM)	0.1	0.25	0.5	0.75
Mass swelling ratio	8.2±0.5	8.0±0.4	8.2±0.3	8.0±0.5

Table S4. Initial swelling ration after of hydrogels synthesized at different acrylamide concentrations (0.5 mM DNA monomer, 10% acrylamide)

Acrylamide (MV%)	6	8	10	15	20
Mass swelling ratio	5.9±0.9	7.2±0.4	8.0±0.3	8.4±0.5	9.1±0.5

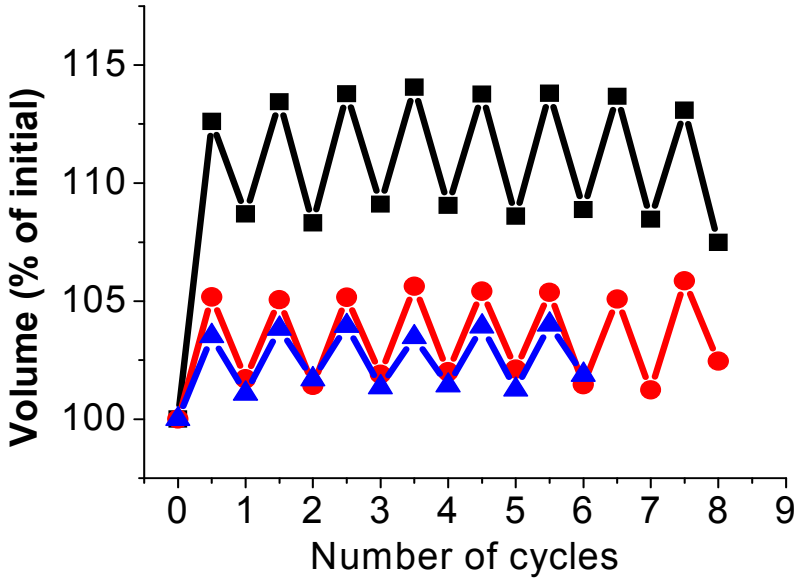

Figure S3. Light-induced reversible swelling and shrinking of the light-responsive dynamic hydrogels synthesized using different concentrations of MBAA (DNA monomer: 0.5 mM; acrylamide: 10%): 0.0033 % (black), 0.0067% (red) and 0.0133% (blue).

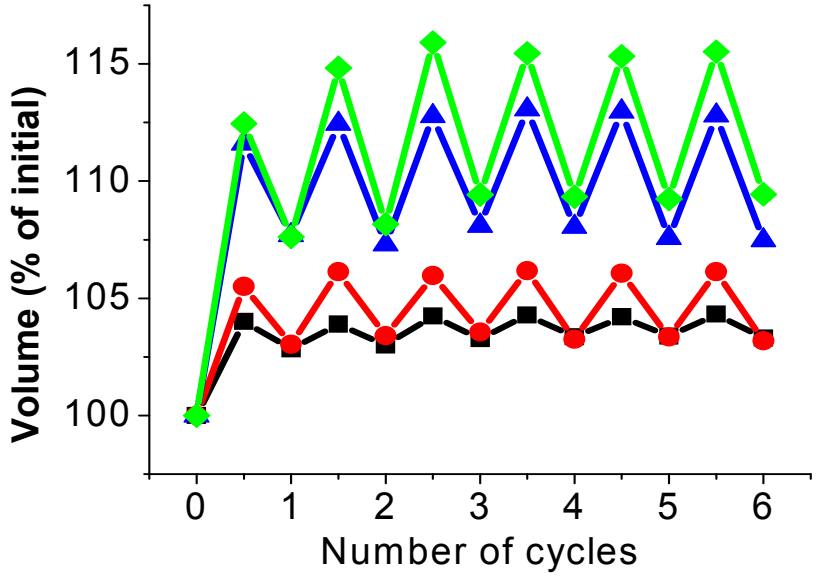

Figure S4. Light-induced reversible swelling and shrinking of the light-responsive dynamic hydrogels synthesized using different concentrations of DNA monomers (MBAA: 0.0033 %; acrylamide: 10%): 0.1 mM (black), 0.25 mM (red), 0.5 mM (blue) and 0.75 mM (green).

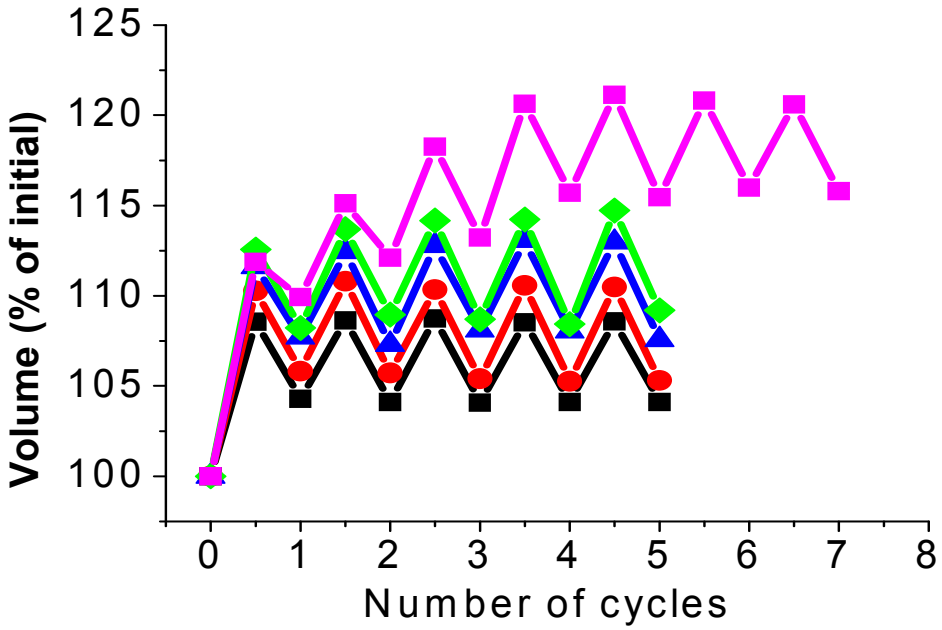

Figure S5. Light-induced reversible swelling and shrinking of the light-responsive dynamic hydrogels synthesized using different concentrations of acrylamide (DNA monomer: 0.5 mM; MBAA: 0.0033%): 6% (black), 8% mM (red), 10% (blue), 15% (green) and 20% (pink).

References:

1 Asanuma, H.; Liang, X.; Nishioka, H.; Matsunaga, D.; Liu, M.; Komiyama, M. Synthesis of Azobenzene-Tethered DNA for Reversible Photo-Regulation of DNA Functions: Hybridization and Transcription. *Nat. Protoc*. **2007**, *2*, 203-212.